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A cost analysis of MH-53E avionics maintenance support alternatives for remote deployment.

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A Cost Analysis of MH-53E Avionics
Maintenance Support Alternatives for
Remote Deployment

by

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The United States Navy is in the process of considering the use of Mobile Maintenance Facilities to provide an intermediate level maintenance capability to MH-53E helicopter minesweeping and countermeasure squadrons of four and seven aircraft while on deployment to remote locations. This thesis considers two alternatives; (1) no intermediate maintenance capability and, (2) full capability. Because of limited data only the repair of avionics components are considered. The alternative corresponding to no maintenance capability provides the increased inventory required to meet expected failures. The second alternative involves all of the elements of intermediate maintenance at a remote site as well as the needed supply support. Present value analyses of the life cycle costs are utilized to determine the least cost alternative. The results suggest that intermediate maintenance activities are the least cost alternative for avionics

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A Cost Analysis of MH-53E Avionics Maintenance Support Alternatives for Remote Deployment

by

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ABSTRACT

The United States Navy is in the process of considering the use of Mobile Maintenance Facilities to provide an intermediate level maintenance capability to MH-53E helicopter minesweeping and countermeasure squadrons of four and seven aircraft while on deployment to remote locations. This thesis considers two alternatives; (1) no intermediate maintenance capability and, (2) full capability. Because of limited data only the repair of avionics components are considered. The alternative corresponding to no maintenance capability provides the increased inventory required to meet expected failures. The second alternative involves all of the elements of intermediate maintenance at a remote site as well as the needed supply support. Present value analyses of the life cycle costs are utilized to determine the least cost alternative. The results suggest that intermediate maintenance activities are the least cost alternative for avionics support for a seven-aircraft detachment and the most costly alternative for the four-aircraft detachment.

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I. INTRODUCTION

The Sikorsky MH-53E helicopter is presently being introduced to the U.S. Navy where it will serve with Helicopter Mine Countermeasures Squadrons Twelve, Fourteen, and Fifteen (HM-12, HM-14, HM-15) performing multi-mission tasking as an airborne minesweeping platform. This helicopter is of similar design to the CH-53E which is in service with the United States Marine Corps. The MH-53E has the peculiar equipment necessary to conduct minesweeping and mine countermeasure operations.

When called upon to deploy to strategic bodies of water, the projected operating environment of the MH-53E helicopter will often be remote locations far from any American military installation. These remote locations may be "austere sights," having no capability of providing maintenance and supply support for the aircraft detachment.

In lieu of sustaining flight operations by lengthy supply lines to supporting repair and supply functions, the Chief of Naval Operations has directed that a MH-53E detachment be capable of intermediate level maintenance on various systems of the MH-53E while on deployment. Mobile Maintenance Facilities (MMF) are being planned to provide the self-contained support for the intermediate level repair activity. The containers for these facilities have

international standard dimensions that are the same as commercial containers to facilitate transportation by land, sea or air. Mobile Maintenance Facilities are currently being procured to support MH-53E squadrons on both coasts.

The intermediate level repair support provided by the MMF at a remote location is not a follow-on project to be considered after the MH-53E fleet introduction. Rather, it is an integral part of the helicopter's introduction.

A. PURPOSE

The intent of this thesis is to compare costs of (1) supply support provided by increased inventory of components with (2) the establishment of an intermediate level maintenance repair activity supporting the MH-53E systems when on remote location deployment. These will be noted as Model A and B, respectively.

B. SCOPE OF ANALYSIS

The detachment sizes under current consideration by the Navy are four and seven aircraft. Therefore, the cost comparisons will include both sizes.

Because of the limited data available for the cost analyses, the thesis will concentrate only on the nine major avionics system of the MH-53E. Actual deployment of the MH-53E will not occur until after the fleet introductory period. Therefore this thesis will assume the performance parameters of the projected operational requirements to be

similar to those available from past operations. In particular, the failure rates of the avionics components are derived from fleet-wide historical data.

The two models of supply support, Models A and B, will be the only alternatives presented in this thesis. Alternatives which combine features of both will not be considered.

C. PREVIEW OF ANALYSIS

Chapter II describes the procedure for determining the inventory levels necessary to meet a specified probability of filling a demand for a spare component. This is called a protection level. A 90% protection level is established as a goal. Chapter II also introduces the rotatable pool and attrition rate of repair. Chapter III presents the details of Models A and B. The initial investment expenses of Models A and B are identified. In addition, the continuing costs are calculated. Finally, the net present value of the ten-year life cycle costs for the two models is presented.

Chapter IV compares the present value of the life cycle costs for the two models as developed in Chapter III for both the four and the seven aircraft detachment. Then analyses of model variations which lead to enhanced cost effectiveness are also presented. Finally, sensitivity analyses are performed on the cost models to determine if

changes in the protection levels and percentages of repair parts will affect the choice of the type of supply support for a deployed detachment.

Chapter V summarizes the analyses provided in the thesis and states the conclusions which were reached. The chapter concludes with a list of recommendations for further analysis.

II. SUPPLY SUPPORT LEVELS

A. BACKGROUND

The MH-53E helicopter is presently being introduced to the U.S. Navy in Helicopter Mine Countermeasure Squadron Fifteen and is expected to fulfill the missions and duties outlined in the Chief of Naval Operation's requirement, the Required Operational Capabilities/Projected Operating Environment (ROC/POE). [Ref. 1] Among the requirements of the ROC/POE is the responsibility to deploy to remote locations outside the normal logistic and maintenance support channels afforded by naval air stations and aviation capable ships. Under these conditions the maintenance planners in the squadron must rely upon spare parts packup kits and possible increased levels of component repair capability within the detachment.

This thesis will compare the basic alternatives of (1) increasing spare component inventory with no intermediate repair level, and (2) the establishment of an intermediate level repair capability to prevent having to increase the spare component inventory.

The avionics equipment of MH-53E will be utilized in this chapter to illustrate the trade offs between these concepts. The avionic components which comprise the avionics systems in the aircraft are mature systems utilized in other naval aircraft and have known failure rates.

This chapter describes the procedure for determining projected failures and provisioning policies that are currently used to provide adequate levels of aviation supply support. These procedures will also be used in the next chapter for supply support models of the remote deployment.

B. RELIABILITY AND SUPPLY SUPPORT

Supply support will be defined as providing the spare components necessary for the immediate accomplishment of the unscheduled and scheduled maintenance actions on the MH-53E avionics system over a sixty-day operating period. Component requirements are a function of demand due to failure. Projected failures are determined by the component's failure rate which is derived from fleet repair information or a manufacturer's estimate.

1. Failure Rate

The average rate at which failures occur over a specified time interval is called the failure rate during that interval. This average rate will be denoted by the Greek letter lambda (λ). Its units are "failures per hour".

The Navy's Aviation Maintenance Data System compiles component failures over intervals of known aircraft flight time. The Aviation Supply Office uses this data to compute component failure rates. Failure rates obtained from ASO are listed in under the lambda column of Tables 1 and 2 in Chapter III.

2. The Poisson Distribution

The Poisson distribution is used by the Aviation Supply Office to compute the probabilities of component failure. This is appropriate because the time between failures of electronic equipment can usually be described by the exponential probability distribution. The reliability of a component is equal to the probability of zero failures occurring when an item is in operation for t hours. The mathematical formula is:

[Ref. 2]

$$p(0) = e^{-\lambda t}.$$

The probability of exactly x failures over time can be written in general form as

$$p(x) = \frac{(\lambda t)^x e^{-\lambda t}}{x!}$$

for x = 0, 1, 2, 3, ... n. With n like items in a system the mean number of failures in t hours will be $n\lambda t$ and the general Poisson probability expression becomes:

$$p(x) = \frac{(n\lambda t)^x e^{-n\lambda t}}{n!}$$

The probability of N or fewer failures, P(N), can be determined from:

$$P(N) = \sum_{x=0}^{N} p(x)$$

Suppose a component has failure rate of 0.0012 failures per hour over a 1000-hour interval. Its reliability will be

$$p(0) = e^{-(0.0012 \times 1000)} = 0.3012.$$

The probability that the component can complete the 1000 hour interval with exactly one failure is:

$$p(1) = 1.2\ e^{-1.2} = 0.3614;$$

with exactly two failures:

$$p(2) = \frac{(1.2)^2 e^{-1.2}}{2} = 0.2168;$$

and with exactly three failures:

$$p(3) = \frac{(1.2)^3 e^{-1.2}}{(3)(2)} = 0.0867.$$

The probability of operating for 1000 hours with at most three failures is equal to the cumulative total of the individual probabilities,

$$P(3) = p(0) + p(1) + p(2) + p(3) = 0.9661.$$

These examples illustrate the computations used in determining component performance over time with failed components being replaced immediately upon failure.

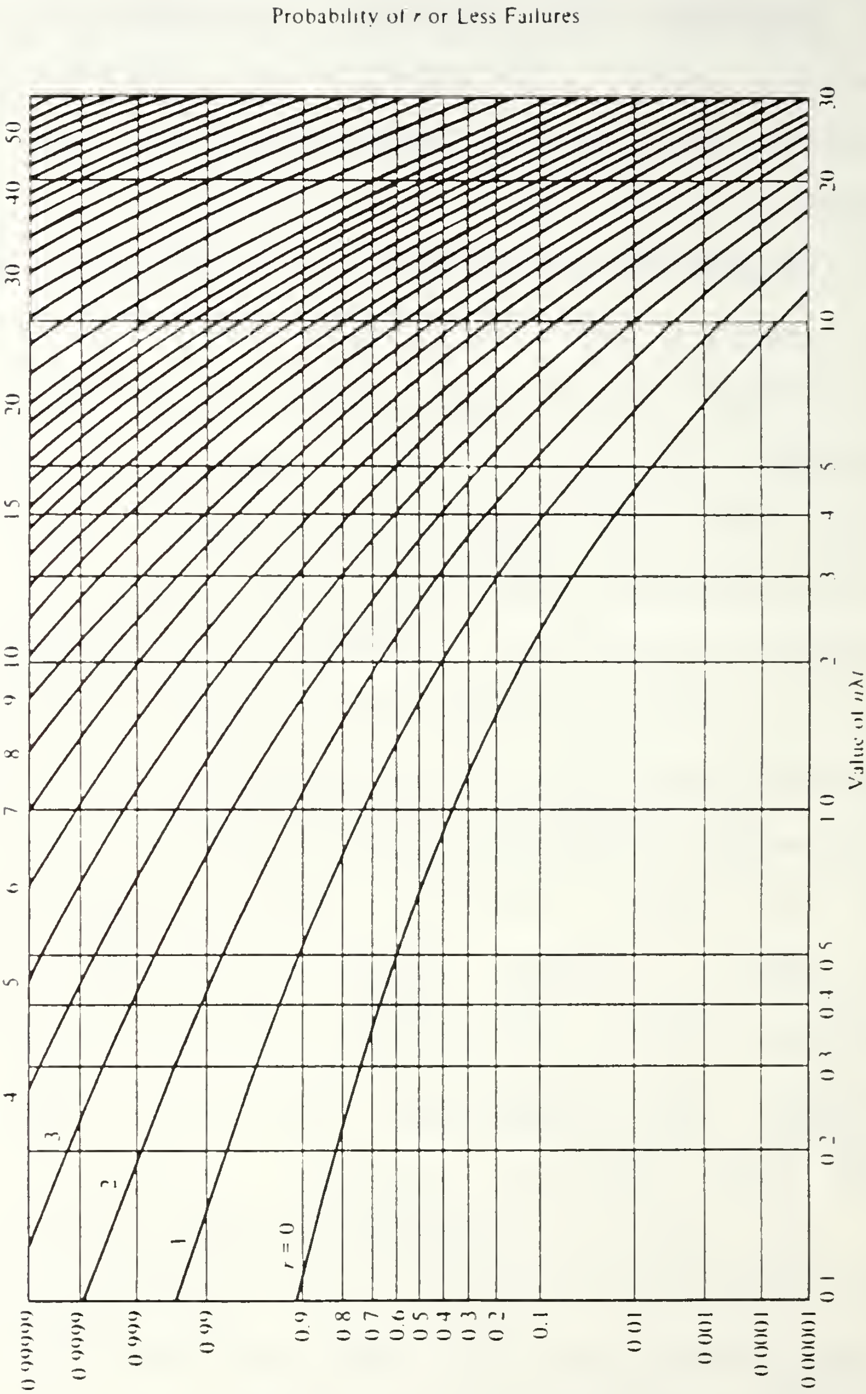
3. Protection Levels

Spare component quantity determination or "depth" is a function of the required probability of having a spare component available when needed, the failure rate of the component, and the quantity of components installed in the

aircraft of the detachment. The probability of having the spare component when required is referred to as the protection level. The selection of a protection level is the first step towards determining the spare quantity required.

Figure 1 illustrates the relationship between the $n\lambda t$ (expected number of failures) and the protection level for a Poisson distribution. [Ref. 3] The horizontal axis corresponds to the expected number of failures. The vertical axis corresponds to the probability of r failures or less (protection level provided by r spares). The curves correspond to the depth r (quantity to be stocked). To use Figure 1 enter the value of $n\lambda t$ on the horizontal axis. Then project vertically to the horizontal line corresponding to the selected protection level on the vertical axis. The curve of r which is just at or slightly above the point is the number of spares needed to provide the desired protection level. For example, if $n\lambda t$ is 3.0 and a 90% protection level is desired then r = 5 is the number of spares to be stocked.

In reality, the protection level goal is a lower bound. The actual protection level provided can be obtained by determining where the r curve intersects the $n\lambda t$ value. Five spares provides an actual protection level of almost 92%.



Protection Level ($x10^{-2}$)

Figure 1: Poisson Cumulative Probabilities.

4. Rotatable Pool and Attrition Rate

With the existence of an intermediate level repair capability many components can be repaired at the remote site. However, it is still necessary to have extra components to replace nonfunctioning components immediately while repair is undertaken on the failed component. The extra components are to be referred to as the "rotatable pool". The size of the rotatable pool is sensitive to the expected demands for a component and the average time to repair (turnaround time). The occasional inability of an intermediate level repair activity to fix an item will also increase the spare component requirements. This inability is commonly referred to as "attrition".

The Aviation Supply Office has established rules and procedures for determining the rotatable pool size for any given ship or shore station providing intermediate maintenance facilities for aircraft. The sizes are provided in tailored computer printouts and provide allowance quantities for a range of flight hours. These are listed in the ASO Allowance Requirement Registers (ARR-100). Unfortunately, these tables correspond to flight hour blocks which are much larger than the 1000 flight hours expected by a deployed MH-53E detachment.

The rotatable pool size can be determined from the Poisson distribution once the expected number of failures is known and the protection level is specified.

Rather than following the ARR approach, the Aviation Supply Office and maintenance planners have developed a spare component packup kit for the MH-53E at NAS Norfolk which provides for one spare component for each item. [Ref. 5] This allows for immediate replacement of only the first failed component. However, since repair turn-around times are typically a few days in length, the single spare should easily provide a protection level in excess of 90% for most of the repairable components. In keeping with this last concept, the models to be considered in Chapter III will assume the rotatable pool quantity for each item will be fixed at one unit per component.

A failure to be able to complete intermediate level repair on a component forces the activity to return the component to supply for subsequent repair at the depot level. This attrition must also be considered in determining the number of spare components to have in a packup kit. ASO computes this allowance for a component as follows.

Attrition Quantity = (MRF) (Total Operating Hours of Component)

The Maintenance Replacement Factor (MRF) is the number of times that a repairable will be beyond the capability of repair at the intermediate level. MRF is included in failure rates by the ASO. Tables 5 and 6 of Chapter III list the MRFs for individual components.

III. DETACHMENT SUPPORT MODEL

This chapter will present the cost models for the alternatives for supply support; (a) an inventory of repairable components, and (b) intermediate level maintenance support supplied by the Mobile Maintenance Facilities (MMF). Four and seven plane detachments are scheduled to deploy [Ref. 6]. Thus, these two levels of detachment size will be assumed and two cost model for each will be presented.

A. DEVELOPMENT OF THE COST MODELS

The two cost models will be referred to as Model A, the "no repair capability" model, which will provide spare parts support without an on-site intermediate level repair activity, and Model B, the "repair capability" model which will provide spare parts support through the on-site intermediate level repair activity.

The relevant costs of model A will be the costs of all spare components necessary to meet expected failures during deployment of a detachment. The initial inventory can be derived by the application of failure rates to the total operating or flight hours projected for a deployment. The Poisson distribution is used to determine the depth of inventory needed to meet the requisite 90% protection level discussed earlier. Costs will also be included which result

from having to replenish this inventory. The Navy Supply Net Price will be utilized to cost out this yearly consumption of the component inventory.

Model B will include all costs associated with the support of the intermediate level maintenance activity. These include the MMF, the tooling and test equipment, transportation, manpower, a consumable allowance for secondary repair parts, the rotatable pool and an average attrition allowance for components.

B. MODEL ASSUMPTIONS

This analysis is limited to the following avionics systems:

AN/ARC-14A Interphone Control System

APN-154 Radar Beacon

APN-171V Altimeter

APX-72 IFF Transponder (with IS 1843 Transponder Tester)

ARN-89 Low Frequency Automatic Distance Finder

A/A24G Altitude Heading and Reference Gyro

AN/ARC 182 UHF/VHF

AN/ARN-118 Tacan

APN-217A Doppler

The following systems were not included because of incomplete or questionable data:

ARC-174A HF Radio

DAFCS-103 Digital Flight Control Systems

ALE-39 Chaff Countermeasures

C. MODEL A COSTS - COMPONENT REPLACEMENT WITHOUT REPAIR

Tables 1 and 2 display the repairable components of the avionics systems by avionics identification number, national stock number, nomenclature, units per application and the failure rate, lambda, expressed in expected failures per flight hour. Flight hours per month, the number of months per deployment, and the number of aircraft supported are stated at the top of each table.

The estimate of the best replacement factor is the product of the failure rate and the expected total operating hours per component over the deployment period. The predicted number of spares required to provide 90% protection is obtained using the Poisson distribution described in Chapter II.

The total cost of this initial spares inventory for Model A is based on a component's replacement price. When the unit replacement cost is multiplied by predicted spares required and the products summed, the total cost of the initial set of spares can be determined.

At the end of each deployment the failed components (carcasses) in the inventory will be returned to a Navy supply center and replacements requisitioned. The costs of the replacements is based on the item's net price. The net price is established for repairable components by the ASO and reflects an item's average repair costs. Tables 3 and 4 display the inventory replenishment costs incurred over a deployment cycle for four and seven aircraft, respectively.

TABLE 1

MODEL A INITIAL INVENTORY LEVELS FOR A FOUR-AIRCRAFT DETACHMENT

ASSUMPTIONS:

Detachment Length:	240 Hours
Number of Aircraft:	4
Poisson Protection Level:	90%

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	LAMBDA	REPLACEMENT FACTOR	PREDICTED SPARES REQUIRED	UNIT COST	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00046	4.86	8	$1,570	$12,560
ARN-118	01-012-4864	Convertor	1	0.00013	0.12	1	$2,030	$2,030
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	0.67	2	$12,460	$24,920
ARN-118	01-012-1920	Control	1	0.00013	0.12	1	$1,380	$1,380
APN-154	00-110-8174	Receiver-Trans.	1	0.00055	0.53	1	$8,330	$8,330
APN-154	00-004-1236	Control	1	0.00039	0.37	1	$876	$876
APN-171	00-933-1802	Indicator	2	0.0006	1.15	3	$3,770	$11,310
APN-171	01-207-8895	Receiver-Trans.	2	0.00461	8.85	13	$15,130	$196,690
APN-171	00-899-0817	Antenna	4	0.0001	0.38	1	$246	$246
APN-217	01-208-0512	Receiver-Trans.	1	0.00204	1.96	4	$168,320	$673,280
APX-72	00-149-1319	Receiver-Trans.	1	0.00478	4.59	7	$7,010	$49,070
APX-72	00-471-3174	Test Set	1	0.00041	0.39	1	$2,640	$2,640
ARN-89	00-001-4074	Amplifier	1	0.009	8.64	12	$86	$1,032
ARN-89	00-001-4076	Control	1	0.00166	1.59	3	$1,620	$4,860
ARN-89	01-021-3288	Receiver	1	0.00111	1.07	2	$3,010	$6,020
ARC-182	01-203-3480	Receiver-Trans.	2	0.00055	1.06	2	$27,280	$54,560
A/A24G	00-993-1485	Controller	1	0.00016	0.15	1	$2,770	$2,770
A/A24G	00-159-2298	Gyroscope	1	0.00182	1.75	4	$30,670	$122,680
						TOTAL		$1,175,254

TABLE 2

MODEL A INITIAL INVENTORY LEVELS
FOR A SEVEN-AIRCRAFT DETACHMENT

ASSUMPTIONS:

Detachment Length:	240 Hours
Number of Aircraft:	7
Poisson Protection Level:	90%

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	LAMBDA	REPLACEMENT FACTOR	PREDICTED SPARES REQUIRED	UNIT COST	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00046	8.50	12	$1,570	$18,840
ARN-118	01-012-4864	Convertor	1	0.00013	0.22	1	$2,030	$2,030
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	1.18	3	$12,460	$37,380
ARN-118	01-012-1920	Control	1	0.00013	0.22	1	$1,380	$1,380
APN-154	00-110-8174	Receiver-Trans.	1	0.00055	0.92	2	$8,330	$16,660
APN-154	00-004-1236	Control	1	0.00039	0.66	2	$876	$1,752
APN-171	00-933-1802	Indicator	2	0.0006	2.02	4	$3,770	$15,080
APN-171	01-207-8895	Receiver-Trans.	2	0.00461	15.49	21	$15,130	$317,730
APN-171	00-899-0817	Antenna	4	0.0001	0.67	2	$246	$492
APN-217	01-208-0512	Receiver-Trans.	1	0.00204	3.43	6	$168,320	$1,009,920
APX-72	00-149-1319	Receiver-Trans.	1	0.00478	8.03	12	$7,010	$84,120
APX-72	00-471-3174	Test Set	1	0.00041	0.69	2	$2,640	$5,280
ARN-89	00-001-4074	Amplifier	1	0.009	15.12	20	$86	$1,720
ARN-89	00-001-4076	Control	1	0.00166	2.79	5	$1,620	$8,100
ARN-89	01-021-3288	Receiver	1	0.00111	1.86	4	$3,010	$12,040
ARC-182	01-203-3480	Receiver-Trans.	2	0.00055	1.85	4	$27,280	$109,120
A/A24G	00-993-1485	Controller	1	0.00016	0.27	1	$2,770	$2,770
A/A24G	00-159-2298	Gyroscope	1	0.00182	3.06	5	$30,670	$153,350
						TOTAL		$1,797,764

TABLE 3

MODEL A EXPECTED COST OF REPLENISHMENT FOR ONE DEPLOYMENT OF FOUR AIRCRAFT

ASSUMPTIONS:

Detachment Length: 240 Hours
Number of Aircraft: 4

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	LAMBDA	REPLACEMENT FACTOR	NET PRICE	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00046	4.86	$561	$2,725
ARN-118	01-012-4864	Convertor	1	0.00013	0.12	$913	$114
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	0.67	$4,710	$3,165
ARN-118	01-012-1920	Control	1	0.00013	0.12	$545	$68
APN-154	00-110-8174	Receiver-Trans.	1	0.00055	0.53	$7,220	$3,812
APN-154	00-004-1236	Control	1	0.00039	0.37	$526	$197
APN-171	00-933-1802	Indicator	2	0.0006	1.15	$1,140	$1,313
APN-171	01-207-8895	Receiver-Trans.	2	0.00461	8.85	$1,910	$16,906
APN-171	00-899-0817	Antenna	4	0.0001	0.38	$246	$94
APN-217	01-208-0512	Receiver-Trans.	1	0.00204	1.96	$58,388	$114,347
APX-72	00-149-1319	Receiver-Trans.	1	0.00478	4.59	$2,180	$10,004
APX-72	00-471-3174	Test Set	1	0.00041	0.39	$902	$355
ARN-89	00-001-4074	Amplifier	1	0.009	8.64	$86	$743
ARN-89	00-001-4076	Control	1	0.00166	1.59	$464	$739
ARN-89	01-021-3288	Receiver	1	0.00111	1.07	$1,140	$1,215
ARC-182	01-203-3480	Receiver-Trans.	2	0.00055	1.06	$8,740	$9,229
A/A24G	00-993-1485	Controller	1	0.00016	0.15	$2,770	$425
A/A24G	00-159-2298	Gyroscope	1	0.00182	1.75	$6,740	$11,776
							$177,229

TABLE 4

MODEL A EXPECTED COST OF REPLENISHMENT
FOR ONE DEPLOYMENT OF SEVEN AIRCRAFT

ASSUMPTIONS:

Detachment Length: 240 Hours
Number of Aircraft: 7

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	LAMBDA	REPLACEMENT FACTOR	NET PRICE	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00046	8.50	$561	$4,769
ARN-118	01-012-4864	Convertor	1	0.00013	0.22	$913	$199
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	1.18	$4,710	$5,539
ARN-118	01-012-1920	Control	1	0.00013	0.22	$545	$119
APN-154	00-110-8174	Receiver-Trans.	1	0.00055	0.92	$7,220	$6,671
APN-154	00-004-1236	Control	1	0.00039	0.66	$526	$345
APN-171	00-933-1802	Indicator	2	0.0006	2.02	$1,140	$2,298
APN-171	01-207-8895	Receiver-Trans.	2	0.00461	15.49	$1,910	$29,585
APN-171	00-899-0817	Antenna	4	0.0001	0.67	$246	$165
APN-217	01-208-0512	Receiver-Trans.	1	0.00204	3.43	$58,388	$200,107
APX-72	00-149-1319	Receiver-Trans.	1	0.00478	8.03	$2,180	$17,506
APX-72	00-471-3174	Test Set	1	0.00041	0.69	$902	$621
ARN-89	00-001-4074	Amplifier	1	0.009	15.12	$86	$1,300
ARN-89	00-001-4076	Control	1	0.00166	2.79	$464	$1,294
ARN-89	01-021-3288	Receiver	1	0.00111	1.86	$1,140	$2,126
ARC-182	01-203-3480	Receiver-Trans.	2	0.00055	1.85	$8,740	$16,152
A/A24G	00-993-1485	Controller	1	0.00016	0.27	$2,770	$745
A/A24G	00-159-2298	Gyroscope	1	0.00182	3.06	$6,740	$20,608
							$310,150

The establishment of the initial inventory incurs costs which will not recur after the initial depth is established and hence can be viewed as a front-end investment. The continuing restocking costs of Model A can be viewed as recurring. The present value of these costs over the expected ten-year life cycle of the aircraft will be presented later in this chapter after the Model B formulation.

D. MODEL B - INTERMEDIATE LEVEL REPAIR COSTS

The costs for providing an on-site intermediate level of repair include the costs of the facilities, tooling and special test equipment, transportation, manpower, an allowance for the "bit and piece" secondary level repair parts, the rotatable pool allowance and the average attrition costs of components.

1. Mobile Maintenance Facilities

The concept of the Mobile Maintenance Facility is to provide the stable environment for the standardized aircraft maintenance that the complex Airborne Mine Countermeasures (AMCM), avionics, and structural systems on this aircraft require. The Mobile Maintenance Facility facilitates the intermediate level of repair in an austere location by providing the technician a stable, self contained environment for his work center. The Mobile Maintenance Facility is an 8' x 8' x 20' aluminum container with an integral air conditioner/heat pump, lights and internal

wiring to distribute electric current in 60 and 400 cycle of 120/220 voltage alternating current and 28 volts direct current.

These work centers have traditionally been composed of hard-wired test benches. However, easily transportable avionics testers in hard shell "suitcase" containers have been specified for the MH-53E program. This gives the MMF flexibility to change intermediate level maintenance capabilities within the MMF or establish facilities within an AIMD ashore or on an aviation capable ship.

The Mobile Facility, when equipped with standard interior configuration and environmental equipment, will have an estimated cost of $60,000. Of this amount, $25,000 will be for the facility shell and $35,000 will be for interior configuration and environmental equipment. Electrical power for the mobile facilities will be provided by MEP-105A Generators; each detachment will need a primary and a reserve unit. These cost an additional $11,000. Thus, the estimated facilities costs for the stated five-units avionics repair facility will be $311,000. [Ref. 6]

2. <u>Test and Repair Equipment</u>

Repair capabilities depend on the test equipment provided. The following list details the procurement costs for that equipment for each avionics system listed in Section B. [Ref. 7]

Peculiar equipment (by system)	Cost
AIC-14A	$ 27,483
APN-154A	104,270
APN-171V	67,945
APX-72 AND IS 1843	87,250
ARN-89	38,174
A/A24G	165,725
ARC-182	10,370
ARN 118	98,918
AN/APN 217A	804,305
Total Cost:	$1,404,440

3. Manpower

The manpower requirements of the intermediate maintenance activity have been outlined in the proposed Naval Training Plan for HM-15. A total of eight technicians are to be assigned to the intermediate level repair activity. [Ref. 8]

Compensation and support costs of these personnel will be computed utilizing direct compensation costs provided by a study conducted by the Center for Naval Analysis. [Ref. 9] Compensation costs are limited to the direct costs of pay and compensation, retirement funding and other direct cost associated with personnel. The NAC has determined that the mean cost for an enlisted man is $1,990 per month.

Remote location support costs will be assumed to be limited to the Navy Basic Allowance for Subsistence (BAS) standard of $5.89 per day. The BAS rate will be $176 per month.

Total compensation costs for manpower in this model will therefore be $2,166 per month. Eight technicians attached to a deployed detachment for two months will incur $34,656 in recurring costs yearly assuming one deployment per year.

4. <u>Transportation</u>

Transportation costs for the MMF must also be addressed. Five MMFs fill an Air Force C-141 cargo plane. The estimated costs of transporting a complement of five Intermediate level MMFs from NAS Norfolk to Sigonella, Sicily is offered for comparison. This cost is $34,480. The cost is based on the Military Airlift Command Critical Mission Rate for a C-141 over this route. Round trip costs would be $68,960.

5. <u>Secondary Repair Costs</u>

Intermediate level component repair is heavily dependent upon an inventory of consumable "bit and piece" parts to install in malfunctioning components. Determining the actual quantities and their associated costs for the intermediate level consumable parts is beyond the scope of this thesis. For this reason Model B will include a cost estimation obtained from applying a percentage to the total

net replenishment price from Model A after deducting the attrition expected in Model B. For example, if the projected usage of a repairable components in Table 4 has a total net cost of $310,150 and the intermediate repair activity was unable to repair $54,560 worth of components, Model B should only expend consumable parts to repair $255,590. The process which was used to determine the value of the consumable allowance from the net price follows.

The net price is a product of industrial repair prices, both Navy and commercial, and a Naval Supply System sponsored Net Price Factor. The Net Price Factor covers freight and handling, depot level attrition, inventory maintenance, carcass losses, and a price stabilization inflation factor. The Net Price Factor for FY87 is 49.5%. [Ref. 10] This factor creates a surcharge of 49.5% which is added to the repair price to obtain the net price. The latter is shown in Table 3 for components listed in that table. Since only the net prices are known for the avionics systems being considered in the cost analysis, the repair prices can be computed as two-thirds of the net price.

Next, average total costs of direct materials for avionics repair at all the Naval Aviation Depots is 55% of total repair expenditures. [Ref. 11] Assuming it is appropriate for an intermediate repair facility, this factor can then be multiplied by the repair price to obtain an

estimate of the costs of repair parts to fix a given broken component. The value of 36.78% is the resulting consumable allowance factor for Model B. This percentage will be assumed for the cost analyses.

To illustrate the process, consider a simple example. If a component has a net price of $100, its repair price will be $66.88. The estimate for the cost of consumable repair parts needed to repair a failed component will be 55% of the repair cost or $36.78.

6. Rotatable Pool and Attrition

Inventory levels to support the rotatable pool are set at one unit per application as discussed in Chapter II. The unit costs of the components in the rotatable pool inventory can be obtained from Table 1 of Chapter II. Attrition allowances are also established in accordance to the formula presented in Chapter II. The Maintenance Replacement Factor is multiplied by the total annual operating hours per component to arrive at the average annual attrition level for each component. This attrition level reflects those maintenance actions which could not be successfully performed at the intermediate level activity during the deployment. The yearly attrition level is multiplied by the component's net price to obtain the attrition expense for the component each year. Tables 5 and 6 list the attrition factors and the total annual expense for attrition.

TABLE 5

ANNUAL COSTS OF ATTRITION FOR MODEL B
FOR A FOUR AIRCRAFT DETACHMENT

ASSUMPTIONS:

Detachment Length: 240 Hours
Number of Aircraft: 4

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	MRF	REPLACEMENT FACTOR	NET PRICE	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00005	0.53	$561	$296
ARN-118	01-012-4864	Convertor	1	0.00013	0.12	$913	$114
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	0.67	$4,710	$3,165
ARN-118	01-012-1920	Control	1	0.00013	0.12	$545	$68
APN-154	00-110-8174	Receiver-Trans.	1	0.00019	0.18	$7,220	$1,317
APN-154	00-004-1236	Control	1	0.0001	0.10	$526	$50
APN-171	00-933-1802	Indicator	2	0.00036	0.69	$1,140	$788
APN-171	01-207-8895	Receiver-Trans.	2	0.00011	0.21	$1,910	$403
APN-171	00-899-0817	Antenna	4	0.0001	0.38	$246	$94
APN-217	01-208-0512	Receiver-Trans.	1	0.00018	0.17	$58,388	$10,089
APX-72	00-149-1319	Receiver-Trans.	1	0.00009	0.09	$2,180	$188
APX-72	00-471-3174	Test Set	1	0.00014	0.13	$902	$121
ARN-89	00-001-4074	Amplifier	1	0.0002	0.19	$86	$17
ARN-89	00-001-4076	Control	1	0.00038	0.36	$464	$169
ARN-89	01-021-3288	Receiver	1	0.00038	0.36	$1,140	$416
ARC-182	01-203-3480	Receiver-Trans.	2	0.0001	0.19	$8,740	$1,678
A/A24G	00-993-1485	Controller	1	0.00016	0.15	$2,770	$425
A/A24G	00-159-2298	Gyroscope	1	0.00182	1.75	$6,740	$11,776
							$31,177

TABLE 6

ANNUAL COSTS OF ATTRITION FOR MODEL B FOR A SEVEN AIRCRAFT DETACHMENT

ASSUMPTIONS:

Detachment Length:	240 Hours
Number of Aircraft:	7

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	MRF	REPLACEMENT FACTOR	NET PRICE	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00005	0.92	$561	$518
ARN-118	01-012-4864	Convertor	1	0.00013	0.22	$913	$199
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	1.18	$4,710	$5,539
ARN-118	01-012-1920	Control	1	0.00013	0.22	$545	$119
APN-154	00-110-8174	Receiver-Trans.	1	0.00019	0.32	$7,220	$2,305
APN-154	00-004-1236	Control	1	0.0001	0.17	$526	$88
APN-171	00-933-1802	Indicator	2	0.00036	1.21	$1,140	$1,379
APN-171	01-207-8895	Receiver-Trans.	2	0.00011	0.37	$1,910	$706
APN-171	00-899-0817	Antenna	4	0.0001	0.67	$246	$165
APN-217	01-208-0512	Receiver-Trans.	1	0.00018	0.30	$58,388	$17,657
APX-72	00-149-1319	Receiver-Trans.	1	0.00009	0.15	$2,180	$330
APX-72	00-471-3174	Test Set	1	0.00014	0.24	$902	$212
ARN-89	00-001-4074	Amplifier	1	0.0002	0.34	$86	$29
ARN-89	00-001-4076	Control	1	0.00038	0.64	$464	$296
ARN-89	01-021-3288	Receiver	1	0.00038	0.64	$1,140	$728
ARC-182	01-203-3480	Receiver-Trans.	2	0.0001	0.34	$8,740	$2,937
A/A24G	00-993-1485	Controller	1	0.00016	0.27	$2,770	$745
A/A24G	00-159-2298	Gyroscope	1	0.00182	3.06	$6,740	$20,608
							$54,560

7. Summary of Model B Cost Elements

All of the Model B cost elements for both the four- and seven-aircraft detachments are listed in Tables 7 and 8. These include the MMF acquisition costs, special tooling and test equipment, manpower, transportation, consumable allowance, the inventory level necessary to support the rotatable pool and its attrition allowance.

E. PRESENT VALUE ANALYSIS

Tables 7 and 8 also list the net present value for the life cycle costs associated with Models A and B. These include the total acquisition and annual support costs over a ten-year life cycle period. The annual costs assume that only one sixty-day deployment to a remote location occurs each year. The procurement costs were assumed to be incurred at the start of the first year and the annual costs were assumed to occur at the end of each year.

The present value of the various costs was determined using the discount rate of 10%. This rate reflects the Capital Budgeting Rate presently utilized in the Naval Air Systems Command. [Ref. 12] Because transactions that accrue in the future cannot be directly compared to investments made at the present due to the time value of money, discounting converts the future costs to their equivalent amounts at the present time to make a valid comparison of alternative decisions.

TABLE 7

NET PRESENT VALUE ANALYSIS OF THE MODELS
WITH FOUR AIRCRAFT

<u>MODEL A</u>

Investment in Allowance Inventory	$1,175,254
Total Annual Inventory Replacement Cost ..	$ 177,229
NET PRESENT VALUE OF MODEL A	$2,363,840

<u>MODEL B</u>

INVESTMENT COSTS:

Five MMFs at $60,000 (+11k)	$ 311,000
Total Test and Repair Equipment	$1,404,440
Rotatable Pool Inventory	$ 289,198
Total Investment Costs	$2,004,638

RECURRING YEARLY COSTS:

Transportation	$ 68,960
Consumable Allowance	$ 53,717
Attrition	$ 31,177
8 Personnel @ $4,332	$ 34,656
Total Annual Costs	$ 188,510
NET PRESENT VALUE OF MODEL B	$3,162,975

TABLE 8

NET PRESENT VALUE ANALYSIS OF THE MODELS
WITH SEVEN AIRCRAFT

MODEL A

Investment in Allowance Inventory	$1,797,764
Total Annual Inventory Replacement Cost ..	$ 310,150
NET PRESENT VALUE OF MODEL A	$3,703,542

MODEL B

INVESTMENT COSTS:

Five MMFs at $60,000 (+11k)	$ 311,000
Total Test and Repair Equipment	$1,404,440
Rotatable Pool Inventory	$ 289,198
Total Investment Costs	$2,004,638

RECURRING YEARLY COSTS:

Transportation	$ 68,960
Consumable Allowance	$ 94,006
Attrition	$ 54,560
8 Personnel @ $4,332	$ 34,656
Total Annual Costs	$ 252,182
NET PRESENT VALUE OF MODEL B	$3,554,220

Chapter IV presents a discussion of the implications of the costs in Tables 7 and 8 and analyzes variations in Models A and B.

IV. MODEL LIFE CYCLE COST ANALYSIS

The cost models described in Chapter III provide total expected expenditures to either provide sufficient inventory to ensure against a component shortage without on-site repair (Model A) or to support intermediate level maintenance repair activity (Model B). The analyses in this chapter include:

1. Comparison of the base costs for each model as developed in Chapter III.

2. Comparison of each model with the high attrition components excluded.

3. Sensitivity analyses for changes in protection level for Model A and consumable repair part levels for Model B.

This chapter closes with a discussion of other influences on the models and a summary of the chapter.

A. BASE MODELS

Model A contains the costs of repairable components inventoried to meet the 90% protection level for supply support and an annual replenishment cost for failed components. The costs of Model B were compiled from the seven segments of intermediate level repair activities expense. The net present values of the ten-year life cycle costs for each model and each detachment alternative were presented in Tables 7 and 8 of Chapter III and are summarized in Table 9.

TABLE 9

NET PRESENT VALUE OF LIFE CYCLE COSTS

No. of Aircraft	4	7
Model A	$ 2,264,273	$ 3,703,542
Model B	$ 3,089,835	$ 3,426,220

The net present value of Model A for the four aircraft detachment clearly shows a significant cost advantage over Model B. Model A has both a lower initial investment and smaller recurring yearly costs (see Table 7 of Chapter III).

Model B has a lower net present value for the seven aircraft detachment. The large investment costs in Model B are compensated for by lower average annual costs. Within five years Model B becomes the least cost alternative. The initial investment for inventory in Model A is nearly equal to the investment cost of facilities, test and repair equipment and rotatable pool inventory in Model B.

B. AVIONIC SYSTEM ANALYSIS

1. ARN-118 Tacan and A/A24G AHARS

To achieve cost effective component repair, the intermediate level should have the capability for repairing the majority of failed components. Those with high attrition losses are receiving little benefit from the IMA repair capability. The failure rates (lambda values) of the components (see Tables 1 and 2 of Chapter III) should exceed the Maintenance Replacement Factor values (Tables 5 and 6)

if the intermediate maintenance activities are to be able to economically repair the component. If this condition does not exist the IMA should not repair the component. Both the ARN-118 Tacan and the A/A24G Altitude Heading and Reference System have MRF equal to lambda.

The ARN-118 Tacan has been Source Maintainability and Recovery (SM&R) coded to reflect depot level repair. Because MRF for this component equals the failure rate, the model will not assign this component to the intermediate level of repair. As a consequence, the equipment needed to test and repair the ARN-118, valued at $98,918 in Model B, will not be needed even though it was included in the Navy's IMA concept for the MH-53E.

The A/A24G Altitude Heading and Reference System has a MRF that also matches the total failure rate for each component. Although this component is coded for intermediate level maintenance, ASO item managers have stated that minimal repairs at intermediate levels have historically occurred in the fleet [Ref. 13]. The A/A24G test and repair equipment valued at $165,725 is therefore not needed in Model B.

Finally, because the spares for the ARN-118 and the A/A24G can be viewed as "consumables" in both models, the associated costs can be deleted from both models for the sake of comparison.

Table 10 provides the net present value analysis when the ARN-118 Tacan and the A/A24G Altitude Heading and Reference System are not included in either model for a seven-aircraft detachment. Model B's investment costs in test equipment and rotatable pool size or depth are reduced by $313,953 while Model A's initial inventory is reduced $196,910 (see Table 2 of Chapter III). Both models also experience the same reductions in annual costs as attrition in Model B equals the cost of replenishment in Model A. Model B remains the least cost alternative for the seven aircraft detachment.

The four-aircraft detachment was not included in this analysis as Model B remains the high cost alternative even with the deletion of these two systems.

2. <u>APN-154 Radar Beacon</u>

The APN-154 Radar Beacon is not cost effective to repair at the intermediate level while on remote location. This system requires $104,270 of test and repair equipment to perform intermediate level repair. Failure data from Model A (see Table 2 of Chapter III) shows that only 0.92 failures of the receiver-transmitter and 0.66 failures of the control unit are expected each year while deployed with a seven aircraft detachment. For Model A the annual costs of replacing these failed components is $7,016 (see Table 4 of Chapter III) and the initial inventory expense for the APN-154 system is $18,412 (see Table 2 of Chapter III). The investment expense of the test equipment alone would not be

TABLE 10

NET PRESENT VALUE ANALYSIS OF THE MODELS
WITH SEVEN AIRCRAFT AFTER DELETING THE
ARN-118 AND THE A/A24G SYSTEMS

<u>MODEL A</u>

Investment in Allowance Inventory	$1,600,854
Total Annual Inventory Replacement Cost ..	$ 282,940
NET PRESENT VALUE OF MODEL A	$3,339,435

<u>MODEL B</u>

INVESTMENT COSTS:

Five MMFs at $60,000 (+11k)	$ 311,000
Total Test and Repair Equipment	$1,139,797
Rotatable Pool Inventory	$ 239,888
Total Investment Costs	$1,690,685

RECURRING YEARLY COSTS:

Transportation	$ 68,960
Consumable Allowance	$ 94,006
Attrition	$ 27,350
8 Personnel @ $4,332	$ 34,656
Total Annual Costs	$ 244,972
NET PRESENT VALUE OF MODEL B	$3,073,070

recovered by the savings in fixed and annual recurring inventory costs over the ten-year life cycle by having the components of the APN-54 repaired by the intermediate maintenance facility.

Table 11 provides the net present value analysis when the ARN-118, A/A24G and the APN-154 Radar Beacon are not repaired at the intermediate level. The investment costs of Model B are reduced by $104,270 for test and repair equipment and $9,206 for the rotatable pool inventory after the APN-154 Radar Beacon costs are removed. The protection level inventory in Model A is reduced by $18,412 and annual replenishment costs by $7,016. The net present value of life cycle costs for Model A decline by $61,523 while those for Model B decline by $138,632. Obviously, Model B remains the least cost alternative for the seven-aircraft detachment.

When the avionic system deletions are included in the four-aircraft model the total savings do not lower Model B's life cycle costs enough to make Model B the least cost alternative.

C. SENSITIVITY ANALYSES

1. Protection Level

The Model A inventory level was designed to provide a 90% protection level. This level was selected because it corresponds with the level used by the ASO. However, ASO managers have expressed to the author that the 90% level is

TABLE 11

NET PRESENT VALUE ANALYSIS OF THE MODELS WITH SEVEN AIRCRAFT AFTER DELETING THE ARN-118, A/A24G AND APN-154 SYSTEMS

MODEL A

Investment in Allowance Inventory	$1,582,442
Total Annual Inventory Replacement Cost ..	$ 275,924
NET PRESENT VALUE OF MODEL A	$3,277,912

MODEL B

INVESTMENT COSTS:

Five MMFs at $60,000 (+11k)	$ 311,000
Total Test and Repair Equipment	$1,035,527
Rotatable Pool Inventory	$ 230,682
Total Investment Costs	$1,577,209

RECURRING YEARLY COSTS:

Transportation	$ 68,960
Consumable Allowance	$ 92,305
Attrition	$ 24,957
8 Personnel @ $4,332	$ 34,656
Total Annual Costs	$ 220,878
NET PRESENT VALUE OF MODEL B	$2,934,438

viewed as the traditional standard and need not be used as an absolute. Therefore, the author also computed the inventory levels necessary to provide protection level of 80%, 85% and 95%.

Inventory investment costs for Model A for the 80 to 95% protection levels and each detachment alternative are listed in Table 12. A complete listing of the individual component depths for these levels are provided the Appendix.

TABLE 12

MODEL A INVESTMENT COSTS FOR A RANGE OF PROTECTION LEVELS

No. of Aircraft:	4A/C	7A/C
Protection Level:		
80%	$ 921,108	$ 1,500,850
85%	$ 943,334	$ 1,559,404
90%	$ 1,175,254	$ 1,797,764
95%	$ 1,243,138	$ 2,051,142

The initial investment inventory for Model A would decrease as expected when spare components were stocked to a lower protection level. However, the annual recurring inventory costs do not change since replenishment is based on the mean failure rate and not on the protection level. Table 13 lists the base costs for the models (see Table 8 of Chapter III) for a seven-aircraft detachment given an 80%

TABLE 13

NET PRESENT VALUE ANALYSIS OF THE MODELS WITH SEVEN AIRCRAFT UTILIZING 80% PROTECTION LEVEL AND ALL SYSTEMS

<u>MODEL A</u>

Investment in Allowance Inventory	$1,500,850
Total Annual Inventory Replacement Cost ..	$ 310,150
NET PRESENT VALUE OF MODEL A	$3,406,628

<u>MODEL B</u>

INVESTMENT COSTS:	
Five MMFs at $60,000 (+11k)	$ 311,000
Total Test and Repair Equipment	$1,404,440
Rotatable Pool Inventory	$ 289,198
Total Investment Costs	$2,004,638
RECURRING YEARLY COSTS:	
Transportation	$ 68,960
Consumable Allowance	$ 94,006
Attrition	$ 54,560
8 Personnel @ $4,332	$ 34,656
Total Annual Costs	$ 252,182
NET PRESENT VALUE OF MODEL B	$3,554,220

protection level inventory in Model A. The significantly lower initial cost of inventory results in Model A being the least cost alternative.

The two models would have nearly equal life cycle costs if Model A's initial inventory cost $1,650,000. From Table 12 it can be seen that the corresponding protection level would be more than 85% but less than 90% for a seven-aircraft detachment. Thus, Model A will be the least cost alternative for all protection levels less than that "critical" protection level and Model B will be the least cost alternative for all levels greater than that critical level.

Fiscal considerations could demand a reduction of the total cost of a packup inventory kit or physical storage limitations could reduce the weight and cubic feet allowed for an inventory packup kit. By varying the protection levels planners could establish a component packup kit which would obtain the highest protection level available for a fixed cost or storage volume. If planners were willing to allow each component to have a different protection level then an marginal analysis approach could be taken to determine the depth of each component to stock which maximizes the aggregate protection level subject to the budget or space constraint.

2. Consumable Allowance Levels

Chapter III introduced the consumable allowance needed by the intermediate maintenance facility to repair failed components and explained the relationship between net price and the repair price. The expected consumable allowance costs for Model B were assumed to be 36.78% of Model A replenishment costs less a deduction for Model B attrition costs. The net unit price was assumed for the unit replenishment cost. The net price includes average repair costs and a 49.5% surcharge (Net Price Factor) assessed by the Naval Supply System. Thus, the estimate of the actual repair price was assumed to be 66.88% of the net price obtained from ASO. Finally, the direct material costs percentage of total repair expenditures at the Naval Aviation Depots has been 55% of the repair price for avionics components and was assumed appropriate for Model B in Chapter III. However, that percentage may be different for a deployed intermediate repair facility. Therefore, the sensitivity analysis considered in this section includes increasing the percentage of direct material to repair costs from 55% to 65% and also reducing the percentage to 45%. Only Model B will be affected since it only has the consumable allowance.

Table 14 presents the results of these calculations. The costs in Table 14 reflect a seven-aircraft detachment with the ARN-118, A/A24G, and APW-154 systems deleted (Table

11). As the third column shows, the changes in the direct materials percentage resulted in only a 4% change in the total life cycle costs for Model B. Model B remains the least cost model. In fact, Model B remains the least cost alternative even if the direct materials percentage increases to 85%.

The four-aircraft detachment was not analyzed for sensitivity to changes in the direct materials percentage.

TABLE 14

COSTS OF MODEL B CONSUMABLE ALLOWANCE FOR A RANGE OF DIRECT MATERIAL PERCENTAGES

Percentage	Allowance	Total NPV
45	$ 75,312	$2,830,021
55	92,305	2,934,438
65	109,100	3,037,669

D. IMA REPAIR EFFECTIVENESS

Although an analysis of intermediate level repair effectiveness is beyond the scope of this thesis, the performance of the activity while on deployment is crucial. The rotatable pool is designed to serve as immediate replacement for failed components while a component is in repair. Failure of the intermediate repair activity to meet the fleet-wide performance for turn-around time or completion percentage could force an increase in the size of the local rotatable pool and hence increase the costs of Model B.

E. SUMMARY

This chapter has provided several net present value analyses of the two costs models for both the four- and the seven-aircraft detachment models. For the basic Models, developed in Chapter III, the least cost model for avionics supply support for a four-aircraft detachment was Model A, a packup kit with increased depth of spare components. The seven-aircraft detachment should deploy with intermediate level repair facilities as the life cycle costs of model B are lower.

The next analysis considered deleting two avionics systems which actually could not be repaired at the intermediate level. A third system, the APN-154 Radar Beacon, was also removed from the model as its low number of expected failures did not make the repair capability cost-effective. In each case the present value of the life cycle costs were recomputed. Model B continued to be the least cost alternative of avionics support even when these three systems were deleted from the cost models.

In the third analysis, protection levels were varied from 80 to 95% and total costs for each protection level were calculated for Model A for the seven-aircraft detachment. For the 80% protection level, Model A became the least cost alternative.

Finally, sensitivity analysis was performed on the consumable direct material costs for repair parts used to repair components in Model B. Model B costs were found to be relatively insensitive to increases in the direct materials percentage. An increase to 85% would be required before Model A would become the least cost alternative.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

The MH-53E helicopter will be tasked with fleet airborne minesweeping and associated mine countermeasures applications. Intermediate level repair capability for the avionics system is being considered for four- and seven-aircraft detachments when the deployed site lacks traditional intermediate repair capability. The purpose of this thesis was to evaluate the cost of providing supply support to the detachments through the use of increased component inventory (Model A) or a mobile intermediate level repair activity (Model B).

Chapter II begins with a description of component failure rates and the use of the Poisson probability distribution for determining spare component inventory depths needed for a remote deployment packup kit to provide a specific level of protection.

Intermediate level component repair on-site must also include an inventory of components to support the rotatable pool. Following the precedent set by the Aviation Supply Office (ASO), the rotatable pool depth was fixed at one spare unit for each component to be repaired at the intermediate repair activity. The attrition allowance formula for components repairable at the intermediate level was also presented.

Chapter III introduced the details of the two cost models for the major avionics systems of the MH-53E helicopter. Those systems and their components were listed. Data from ASO on costs and failure rates were also listed. Next, the depths of Model A's inventory were calculated to provide enough spares for each component to satisfy the 90% protection level goal for the duration of a detachment's deployment. In addition, the annual recurring costs of replenishing the inventory were computed.

Model B was considered next. It included all of the costs for an on-site intermediate level repair activity. Seven investment categories were identified and their costs determined. These were facilities (MMF), test and repair equipment, transportation, manpower, rotatable pool inventory, consumable allowance, and attrition. The annual recurring costs of Model B consisted of the costs for transportation, manpower, consumable allowance, and attrition replenishment. The present value of the life cycle costs for each model and each detachment size were then computed.

Chapter IV begins with a discussion of the results of the cost analyses for Models A and B provided in Chapter III. Then additional variations of models were considered. First, avionics systems which had none or limited IMA repair capability were deleted as was an avionics system which had low expected failures and expensive test equipment. Next,

the protection level for Model A was varied from 80% to 95% to determine the sensitivity of Model A costs to that parameter. Finally, the sensitivity of the consumable allowance for Model B was examined to determine how much of a change in the direct materials to repair price percentage would be needed to result in Model A being preferred over Model B for a seven-aircraft detachment.

B. CONCLUSIONS

The following conclusions were reached from the analyses conducted in this thesis:

1. The least cost alternative for a four-aircraft detachment is Model A. In other words, with an increased inventory of spare components for the avionics systems is preferred over having an intermediate maintenance activity.

2. The seven-aircraft detachment should utilize the deployed intermediate maintenance facility as the net present value of the life cycle costs is lowest for Model B. Model B will remain the least cost alternative as long as protection levels in Model A are greater than 85%.

3. Avionics systems which have low probabilities of successful repair at the intermediate level should not be selected for intermediate level repair by a deployed activity. In particular, the ARN-118 Tacan and the A/A24G AHARS should not be provided intermediate maintenance capability unless validation of repair effectiveness can be established.

4. Avionics systems which can be more economically supported by increased inventory should not be selected for intermediate level repair. The APN-154 Radar Beacon appears to be such a system.

C. RECOMMENDATIONS

This thesis has considered the alternatives of having and not having an MH-53E Mobile Maintenance Facility

Intermediate Repair Activity. It concentrated on the life cycle cost of investment and annual support expense for the avionics components only. As a consequence the following recommendations for further analyses are made:

1. The failure data on the MH-53E avionics systems in this thesis was based strictly on fleet-wide data obtained from the Aviation Supply Office. MH-53E peculiar data should be utilized to validate the conclusions of this thesis.

2. Intermediate level performance of actual component repair must be analyzed to determine if acceptable rates of repair are within the capability of a remote detachment utilizing the MMFs.

3. Space requirements should be examined to determine if the weight and cube of an increased inventory associated with Model A is feasible to deploy if the MMF repair activity could not be readily deployed. If not, a solution to the problem of a constraint on space or weight can be obtained by marginal analysis to provide a packup kit which has the maximum aggregate protection level for the constraint.

4. Components with depot level repair SM&R codes must be examined to determine if a MH-53E detachment utilizing Mobile Maintenance Facilities could effectively provide repair while on a remote deployment.

5. The analyses in this thesis should be expanded to include the propulsion and airframe systems.

APPENDIX
ALTERNATIVE PROTECTION LEVELS

PROTECTION LEVEL ANALYSIS FOR 80%

ASSUMPTIONS:

Detachment Length: 240 Hours
Number of Aircraft: 4
Poisson Protection Level: 80%

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	LAMBDA	REPLACEMENT FACTOR	PREDICTED SPARES REQUIRED	UNIT COST	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00046	4.86	7	$1,570	$10,990
ARN-118	01-012-4864	Convertor	1	0.00013	0.12	1	$2,030	$2,030
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	0.67	1	$12,460	$12,460
ARN-118	01-012-1920	Control	1	0.00013	0.12	1	$1,380	$1,380
APN-154	00-110-8174	Receiver-Trans.	1	0.00055	0.53	1	$8,330	$8,330
APN-154	00-004-1236	Control	1	0.00039	0.37	1	$876	$876
APN-171	00-933-1802	Indicator	2	0.0006	1.15	2	$3,770	$7,540
APN-171	01-207-8895	Receiver-Trans.	2	0.00461	8.85	11	$15,130	$166,430
APN-171	00-899-0817	Antenna	4	0.0001	0.38	1	$246	$246
APN-217	01-208-0512	Receiver-Trans.	1	0.00204	1.96	3	$168,320	$504,960
APX-72	00-149-1319	Receiver-Trans.	1	0.00478	4.59	6	$7,010	$42,060
APX-72	00-471-3174	Test Set	1	0.00041	0.39	1	$2,640	$2,640
ARN-89	00-001-4074	Amplifier	1	0.009	8.64	11	$86	$946
ARN-89	00-001-4076	Control	1	0.00166	1.59	3	$1,620	$4,860
ARN-89	01-021-3288	Receiver	1	0.00111	1.07	2	$3,010	$6,020
ARC-182	01-203-3480	Receiver-Trans.	2	0.00055	1.06	2	$27,280	$54,560
A/A24G	00-993-1485	Controller	1	0.00016	0.15	1	$2,770	$2,770
A/A24G	00-159-2298	Gyroscope	1	0.00182	1.75	3	$30,670	$92,010
						TOTALS	$289,198	$921,108

PROTECTION LEVEL ANALYSIS FOR 85%

ASSUMPTIONS:

Detachment Length: 240 Hours
Number of Aircraft: 4
Poisson Protection Level: 85%

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	LAMBDA	REPLACEMENT FACTOR	PREDICTED SPARES REQUIRED	UNIT COST	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00046	4.86	7	$1,570	$10,990
ARN-118	01-012-4864	Convertor	1	0.00013	0.12	1	$2,030	$2,030
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	0.67	1	$12,460	$12,460
ARN-118	01-012-1920	Control	1	0.00013	0.12	1	$1,380	$1,380
APN-154	00-110-8174	Receiver-Trans.	1	0.00055	0.53	1	$8,330	$8,330
APN-154	00-004-1236	Control	1	0.00039	0.37	1	$876	$876
APN-171	00-933-1802	Indicator	2	0.0006	1.15	2	$3,770	$7,540
APN-171	01-207-8895	Receiver-Trans.	2	0.00461	8.85	12	$15,130	$181,560
APN-171	00-899-0817	Antenna	4	0.0001	0.38	1	$246	$246
APN-217	01-208-0512	Receiver-Trans.	1	0.00204	1.96	3	$168,320	$504,960
APX-72	00-149-1319	Receiver-Trans.	1	0.00478	4.59	7	$7,010	$49,070
APX-72	00-471-3174	Test Set	1	0.00041	0.39	1	$2,640	$2,640
ARN-89	00-001-4074	Amplifier	1	0.009	8.64	12	$86	$1,032
ARN-89	00-001-4076	Control	1	0.00166	1.59	3	$1,620	$4,860
ARN-89	01-021-3288	Receiver	1	0.00111	1.07	2	$3,010	$6,020
ARC-182	01-203-3480	Receiver-Trans.	2	0.00055	1.06	2	$27,280	$54,560
A/A24G	00-993-1485	Controller	1	0.00016	0.15	1	$2,770	$2,770
A/A24G	00-159-2298	Gyroscope	1	0.00182	1.75	3	$30,670	$92,010
						TOTALS	$289,198	$943,334

PROTECTION LEVEL ANALYSIS FOR 95%

ASSUMPTIONS:

Detachment Length:	240 Hours
Number of Aircraft:	4
Poisson Protection Level:	95%

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	LAMBDA	REPLACEMENT FACTOR	PREDICTED SPARES REQUIRED	UNIT COST	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00046	4.86	9	$1,570	$14,130
ARN-118	01-012-4864	Convertor	1	0.00013	0.12	1	$2,030	$2,030
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	0.67	2	$12,460	$24,920
ARN-118	01-012-1920	Control	1	0.00013	0.12	1	$1,380	$1,380
APN-154	00-110-8174	Receiver-Trans.	1	0.00055	0.53	2	$8,330	$16,660
APN-154	00-004-1236	Control	1	0.00039	0.37	2	$876	$1,752
APN-171	00-933-1802	Indicator	2	0.0006	1.15	3	$3,770	$11,310
APN-171	01-207-8895	Receiver-Trans.	2	0.00461	8.85	14	$15,130	$211,820
APN-171	00-899-0817	Antenna	4	0.0001	0.38	2	$246	$492
APN-217	01-208-0512	Receiver-Trans.	1	0.00204	1.96	4	$168,320	$673,280
APX-72	00-149-1319	Receiver-Trans.	1	0.00478	4.59	8	$7,010	$56,080
APX-72	00-471-3174	Test Set	1	0.00041	0.39	2	$2,640	$5,280
ARN-89	00-001-4074	Amplifier	1	0.009	8.64	14	$86	$1,204
ARN-89	00-001-4076	Control	1	0.00166	1.59	4	$1,620	$6,480
ARN-89	01-021-3288	Receiver	1	0.00111	1.07	3	$3,010	$9,030
ARC-182	01-203-3480	Receiver-Trans.	2	0.00055	1.06	3	$27,280	$81,840
A/A24G	00-993-1485	Controller	1	0.00016	0.15	1	$2,770	$2,770
A/A24G	00-159-2298	Gyroscope	1	0.00182	1.75	4	$30,670	$122,680
						TOTALS	$289,198	$1,243,138

PROTECTION LEVEL ANALYSIS FOR 80%

ASSUMPTIONS:

Detachment Length:	240 Hours
Number of Aircraft:	7
Poisson Protection Level:	80%

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	LAMBDA	REPLACEMENT FACTOR	PREDICTED SPARES REQUIRED	UNIT COST	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00046	8.50	11	$1,570	$17,270
ARN-118	01-012-4864	Convertor	1	0.00013	0.22	1	$2,030	$2,030
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	1.18	2	$12,460	$24,920
ARN-118	01-012-1920	Control	1	0.00013	0.22	1	$1,380	$1,380
APN-154	00-110-8174	Receiver-Trans.	1	0.00055	0.92	2	$8,330	$16,660
APN-154	00-004-1236	Control	1	0.00039	0.66	1	$876	$876
APN-171	00-933-1802	Indicator	2	0.0006	2.02	3	$3,770	$11,310
APN-171	01-207-8895	Receiver-Trans.	2	0.00461	15.49	19	$15,130	$287,470
APN-171	00-899-0817	Antenna	4	0.0001	0.67	1	$246	$246
APN-217	01-208-0512	Receiver-Trans.	1	0.00204	3.43	5	$168,320	$841,600
APX-72	00-149-1319	Receiver-Trans.	1	0.00478	8.03	10	$7,010	$70,100
APX-72	00-471-3174	Test Set	1	0.00041	0.69	1	$2,640	$2,640
ARN-89	00-001-4074	Amplifier	1	0.009	15.12	18	$86	$1,548
ARN-89	00-001-4076	Control	1	0.00166	2.79	4	$1,620	$6,480
ARN-89	01-021-3288	Receiver	1	0.00111	1.86	3	$3,010	$9,030
ARC-182	01-203-3480	Receiver-Trans.	2	0.00055	1.85	3	$27,280	$81,840
A/A24G	00-993-1485	Controller	1	0.00016	0.27	1	$2,770	$2,770
A/A24G	00-159-2298	Gyroscope	1	0.00182	3.06	4	$30,670	$122,680
						TOTALS	$289,198	$1,500,850

PROTECTION LEVEL ANALYSIS FOR 85%

ASSUMPTIONS:

Detachment Length: 240 Hours
Number of Aircraft: 7
Poisson Protection Level: 85%

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	LAMBDA	REPLACEMENT FACTOR	PREDICTED SPARES REQUIRED	UNIT COST	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00046	8.50	12	$1,570	$18,840
ARN-118	01-012-4864	Convertor	1	0.00013	0.22	1	$2,030	$2,030
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	1.18	2	$12,460	$24,920
ARN-118	01-012-1920	Control	1	0.00013	0.22	1	$1,380	$1,380
APN-154	00-110-8174	Receiver-Trans.	1	0.00055	0.92	2	$8,330	$16,660
APN-154	00-004-1236	Control	1	0.00039	0.66	1	$876	$876
APN-171	00-933-1802	Indicator	2	0.0006	2.02	3	$3,770	$11,310
APN-171	01-207-8895	Receiver-Trans.	2	0.00461	15.49	20	$15,130	$302,600
APN-171	00-899-0817	Antenna	4	0.0001	0.67	1	$246	$246
APN-217	01-208-0512	Receiver-Trans.	1	0.00204	3.43	5	$168,320	$841,600
APX-72	00-149-1319	Receiver-Trans.	1	0.00478	8.03	11	$7,010	$77,110
APX-72	00-471-3174	Test Set	1	0.00041	0.69	2	$2,640	$5,280
ARN-89	00-001-4074	Amplifier	1	0.009	15.12	17	$86	$1,462
ARN-89	00-001-4076	Control	1	0.00166	2.79	5	$1,620	$8,100
ARN-89	01-021-3288	Receiver	1	0.00111	1.86	3	$3,010	$9,030
ARC-182	01-203-3480	Receiver-Trans.	2	0.00055	1.85	3	$27,280	$81,840
A/A24G	00-993-1485	Controller	1	0.00016	0.27	1	$2,770	$2,770
A/A24G	00-159-2298	Gyroscope	1	0.00182	3.06	5	$30,670	$153,350
						TOTALS	$289,198	$1,559,404

PROTECTION LEVEL ANALYSIS FOR 95%

ASSUMPTIONS:

Detachment Length:	240 Hours
Number of Aircraft:	7
Poisson Protection Level:	95%

SYSTEM	STOCK NUMBER	NOMENCLATURE	UNIT PER APPL	LAMBDA	REPLACEMENT FACTOR	PREDICTED SPARES REQUIRED	UNIT COST	TOTAL COST
AIC-14A	00-008-5602	Control Intercom	11	0.00046	8.50	14	$1,570	$21,980
ARN-118	01-012-4864	Convertor	1	0.00013	0.22	1	$2,030	$2,030
ARN-118	01-012-1938	Receiver-Trans.	1	0.0007	1.18	3	$12,460	$37,380
ARN-118	01-012-1920	Control	1	0.00013	0.22	1	$1,380	$1,380
APN-154	00-110-8174	Receiver-Trans.	1	0.00055	0.92	3	$8,330	$24,990
APN-154	00-004-1236	Control	1	0.00039	0.66	2	$876	$1,752
APN-171	00-933-1802	Indicator	2	0.0006	2.02	5	$3,770	$18,850
APN-171	01-207-8895	Receiver-Trans.	2	0.00461	15.49	23	$15,130	$347,990
APN-171	00-899-0817	Antenna	4	0.0001	0.67	2	$246	$492
APN-217	01-208-0512	Receiver-Trans.	1	0.00204	3.43	7	$168,320	$1,178,240
APX-72	00-149-1319	Receiver-Trans.	1	0.00478	8.03	13	$7,010	$91,130
APX-72	00-471-3174	Test Set	1	0.00041	0.69	2	$2,640	$5,280
ARN-89	00-001-4074	Amplifier	1	0.009	15.12	23	$86	$1,978
ARN-89	00-001-4076	Control	1	0.00166	2.79	6	$1,620	$9,720
ARN-89	01-021-3288	Receiver	1	0.00111	1.86	4	$3,010	$12,040
ARC-182	01-203-3480	Receiver-Trans.	2	0.00055	1.85	4	$27,280	$109,120
A/A24G	00-993-1485	Controller	1	0.00016	0.27	1	$2,770	$2,770
A/A24G	00-159-2298	Gyroscope	1	0.00182	3.06	6	$30,670	$184,020
						TOTALS	$289,198	$2,051,142

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